Analysis and Design of G + 5 Residential Building done by using ETABS

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Abstract - *These days, urban areas are growing fast and so is the need for G+5 residential buildings. But before we build anything, we have to be sure the structure is safe. That's why I took up this project to analyze and design a G+5 RCC building using ETABS. First, I prepared the structural model in ETABS based on the architectural plan. Then I applied all the relevant loads: dead load, live load, along with wind and earthquake loads. After running the analysis, I checked the story displacement, made sure the drift was within limits, and looked at the bending moments in beams and axial forces in columns. Once I verified the results, I designed all structural elements following IS 456 and IS 1893 codes. Working on this project helped me get comfortable with ETABS. I actually understood how loads impact a building and what precautions we need during design. The analysis confirmed that the building is safe all design checks passed and the sections have enough strength. So ETABS not only saves time but also helps us achieve an economical design. That's what I learned from this project.*

Key Words: Structural Analysis, ETABS, G+5 Residential Building, AutoCAD, IS 456:2000, Load Analysis, Load Combinations, Reinforced Concrete Design, Foundation Design, High-Rise Structures.

1. INTRODUCTION

Over the last decade, Indian cities have seen a huge rise in the number of multi-story residential buildings. This is mainly because of rapid urbanization, population growth, and the shortage of open land in city areas. With land prices going up every year, constructing buildings vertically has become the most practical way to provide housing for more families within limited space. But as buildings get taller, the risk from wind and earthquakes also increases. So proper structural planning, analysis, and design have become more important than ever to make sure the building is safe throughout its design life. Structural design is not just about assuming sizes for beams, columns, and slabs. It's a step-by-step process where we first understand all the loads acting on the building. These include dead load from the weight of members, live load from people and furniture, wind load due to air pressure, and seismic load from earthquakes. All these forces must be transferred safely through beams and columns to the foundation and then to the soil. If any part of this load path is weak, the entire structure can fail. That's why a detailed structural analysis is done before finalizing any member size. In the past, engineers used manual methods and approximate calculations for analysis. But these methods take a lot of time and are not accurate for large or irregular buildings. Today, with the help of computers, we have powerful structural software that can solve complex problems in minutes. These tools can model the exact 3D shape of the building, apply all types of loads, and show how each member behaves. Among all the software available, ETABS is the most popular for RCC buildings. It is specially made for tall buildings and has built-in Indian Standard codes, which makes design work much easier. In this project, I have taken a G+5 residential building plan and done its complete analysis and design using ETABS software. The building was modelled in 3D and analyzed for dead load, live load, wind load, and earthquake load as per IS 875 and IS 1893. After the analysis, I designed all major structural elements like slabs, beams, columns, staircases, and isolated footings as per IS 456:2000. The main objective was to check if the building is safe against deflection, bending, shear, and story drift. This project gave me practical knowledge of how software is used in real design offices. It also helped me understand how the theory we study in subjects like Structural Analysis and RCC Design is applied to actual projects.

1.1 Problem Statement

In recent years, the number of G+5 and taller residential buildings has gone up because cities don't have enough land for individual houses. But when we go for multi-story construction, the structural design is not simple anymore. The building has to safely carry dead loads, live loads, wind loads, and earthquake forces for its entire life. If any of these loads are not considered properly, it can lead to cracks, excessive deflection, or even failure. 4 The main problem with multi-story buildings is the complexity. There are dozens of beams, columns, and slabs, and each member behaves differently under various load combinations. If we try to analyze this kind of structure manually, it takes weeks and the chances of errors are very high. It is also not possible to accurately predict things like story drift or how the load gets distributed in each frame using hand calculations. Because of this, structural engineers now depend on software tools to do the analysis and design. In this project, I am addressing this problem by using ETABS to model and analyze a G+5 residential building. The idea is to check whether the building remains safe and stable under all possible loads, and to design all structural elements as per IS codes.

1.2 Motivation

Seeing the number of multi-story buildings coming up in cities made me curious about how these structures are actually designed and analyzed before construction. With the continuous increase in housing demand, G+5 residential buildings have become very common in urban areas. While studying structural engineering subjects, I started wondering how engineers ensure that these buildings are safe under different loads. This curiosity led me to choose this project on the analysis and design of a G+5 residential building using ETABS software. In college, we learn a lot of concepts like load calculations, bending moments, shear forces, and design of beams and columns. But all of that is mostly theoretical. It is hard to visualize how these concepts are applied to a complete building in real life. Through this project, I wanted to see how different structural members work together and how loads are transferred from the slab to beams, then to columns, and finally to the foundation. This kind of practical understanding is not possible with textbook problems alone. Another important reason for selecting this topic was to get hands-on experience with ETABS. It is one of the most widely used software tools in structural design offices today. By working on this project, I learned how to create an accurate structural model, apply loads as per IS codes, run the analysis, and design the members properly. I also understood how important it is to follow a systematic procedure to avoid errors. I believe the knowledge and experience I gained from this project will help me a lot in my higher studies and also when I start working as a professional engineer.

1.2 Objectives

The main aim of this project is to do the complete structural analysis and design of a G+5 residential building using ETABS, and to see how the building behaves under actual site conditions. In college we study a lot of theory, but this project gave me a chance to apply those concepts to a real building and check how software helps in the design process.

2. LITERATURE REVIEW

- S. Syed Firoz et al. (2020) investigated the structural analysis and design of a G+5 reinforced concrete residential building using ETABS under gravity and seismic loading conditions. The building was modeled in three dimensions, and the design was carried out in accordance with IS 456:2000 and IS 1893 (Part 1):2016.

- The study demonstrated that ETABS significantly reduced the analysis and design time while providing accurate visualization of load transfer from slabs to beams and columns. The authors concluded that ETABS is an efficient tool for the analysis and economical design of medium-rise buildings.

- However, they emphasized that the reliability of the results depends on accurate structural modeling, proper support conditions, and correct material properties.

- P. Pradeep Kumar (2019) evaluated the seismic performance of a G+5 reinforced concrete building located in Seismic Zone III by comparing conventional manual calculations with ETABS analysis. The study focused on key seismic response parameters such as story displacement, story drift, and base shear. The results indicated that ETABS provides a more realistic distribution of lateral forces, leading to optimized member sizes and economical structural designs while satisfying the requirements of the relevant Indian Standards. The author recommended that critical structural members should be verified through manual calculations to ensure the accuracy and reliability of software-generated results.

- K. Mahesh (2021) conducted a structural analysis of a G+5 reinforced concrete building subjected to both wind and seismic loads in accordance with IS 875 and IS 1893. The study assessed parameters such as story displacement, story drift, and base shear. The results showed that increasing the size of exterior columns effectively controlled excessive story drift and improved overall structural stability. The study also demonstrated that ETABS facilitates design optimization by reducing unnecessary material consumption without compromising safety. However, the author noted that modeling complex structures with irregular geometries requires experienced users and adequate computational resources. Overall, the reviewed literature indicates that ETABS is a reliable and efficient software for the structural analysis and design of multi-story reinforced concrete buildings.

3. METHODOLOGY

From the literature studies conducted on high-rise building analysis using ETABS, a comprehensive understanding of structural behavior under different loading conditions has been obtained. Based on these contributions, a systematic methodology is proposed for the analysis and design of a G+5 Residential Building structure. The methodology involves a collection of building data, model creation in ETABS, design of structural elements etc.

1) **Collection of Building Data** The first step in the project was collecting all required building data. I checked the plan for number of floors, room layout, floor height, and overall dimensions. For G+5, I took floor height as 3m and total height as 21m. I selected M25 concrete and Fe500 steel as per IS 456:2000. For wind, I used 44 m/s for Warangal location, and for earthquake I took Zone II with Soil Type II as per IS 1893:2016. Accurate data collection is important because any wrong input will affect the entire ETABS results.

2) **Model Creation in ETABS** After data collection, I created the G+5 building model in ETABS. First, I set the grid lines and story levels based on the building plan. Then I added beams, columns, and slabs into the model as per drawings. This model represents the actual building and is used for further analysis. Careful modelling is important to get realistic behavior and correct design results. This is a main step in the analysis process.

3) **Definition of Structural Elements** to Once the model was ready, I defined the main structural components in ETABS. Beam, column, slab, and foundation sizes were assigned based on building requirements and preliminary design. The selected sizes match the actual structural arrangement to get realistic results. Proper definition of members helps in understanding load transfer in the structure and gives a strong base for analysis and design.

4) **Assignment of Material Properties** The next step was assigning material properties for analysis. I defined M25 concrete and Fe500 steel in the ETABS model as per project requirements. Material properties play a key role in deciding the strength and behavior of the building. By giving correct values, the software can simulate the actual response of the building under different loads. This step is important for accurate analysis.

5) **Load Calculation and Assignment** For the analysis, I identified all the loads that act on the building and applied them in the ETABS model. I considered dead load, live load, wind load, and seismic load. I calculated the load values using IS code rules and the project requirements. After finding the loads, I assigned them in ETABS for analysis. Applying loads correctly is important because it shows how the building actually behaves and gives reliable design results. safety and economy.

6) **Definition of Load Combinations** In real life, a building does not take only one load at a time. Different loads act together. So, I used load combinations in the analysis. I selected the combinations from IS 456:2000, IS 875, and IS 1893 codes to find the worst loading case for design.

   The main combinations I used are:

   - 1.5(DL + LL)
   - 1.2(DL + LL + EQ)
   - 1.5(DL + EQ)
   - 0.9DL ± 1.5EQ

Where DL = Dead Load, LL = Live Load, and EQ = Earthquake Load.

7) **Structural Analysis** After completing the model and applying all loads, I ran the analysis in ETABS. The software gave results like member forces, support reactions, story displacement, and story drift. These results helped me understand how the building reacts under dead load, live load, wind, and earthquake. This analysis step is the base for design and also shows which members are critical in the structure.

8) **Results Interpretation** running the analysis, I carefully checked all the results. I looked at values like bending moment, shear force, axial load, story displacement, and story drift to see how the building is performing. By checking these results, I confirmed whether the structure is safe as per IS code limits or not. This step helped me decide if any changes are needed before doing the final design.

9) **Design of Structural Elements** Based on the analysis results, I designed all structural members using the correct IS code rules. I designed beams, columns, slabs, and foundations so that they can safely carry all the applied loads. While designing, I made sure the building has enough strength, stability, and serviceability for its full life. The design was done to be safe as well as economical.

10) **Verification and Optimization** After completing the design, I checked all members again to confirm they meet strength and stability requirements. I verified bending, shear, deflection, and story drift values as per code provisions. Where the size was not enough, I changed member dimensions and reinforcement to make the design safe and cost-effective. This verification step ensures the building can handle all expected loads during its service life.

11) **Preparation of Design Reports and Drawings** The last step of the project was preparing design reports and structural drawings. In the report I included analysis results, design calculations, and key observations from the study. I also prepared structural drawings showing reinforcement details and arrangement of beams, columns, slabs, and footings. These documents give a clear record of the full design process and are useful for actual construction.

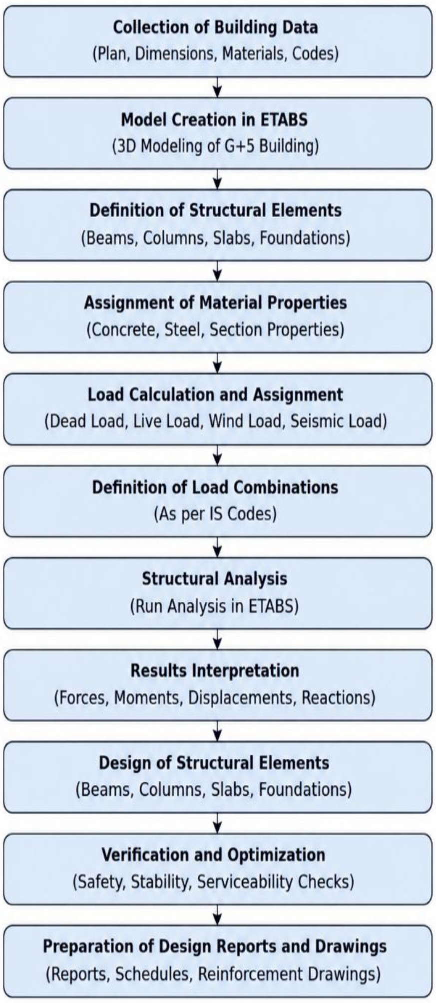

Fig -1: Methodology for G+5 Residential Building Structural Analysis

4. RESULTS AND ANALYSIS

A. **Structural Analysis Results** The G+5 reinforced concrete residential building was modeled and analyzed using ETABS software. The structural model was developed according to the architectural layout, and the analysis was carried out considering the relevant load combinations specified in IS 456:2000, IS 875 (Part 1 & Part 2), and IS 1893 (Part 1):2016. The applied loads include Dead Load (DL), Live Load (LL), Wind Load (WL), and Seismic Load (EL).

B. The analysis generated structural responses such as bending moments, shear forces, axial forces, story displacement, story drift, and support reactions. These results were used for the design of beams, columns, slabs, and foundations.

C. The analysis indicates that the building performs satisfactorily under all considered loading conditions. The critical load combinations were identified, and all structural members were designed within the permissible limits specified by the Indian Standard codes.

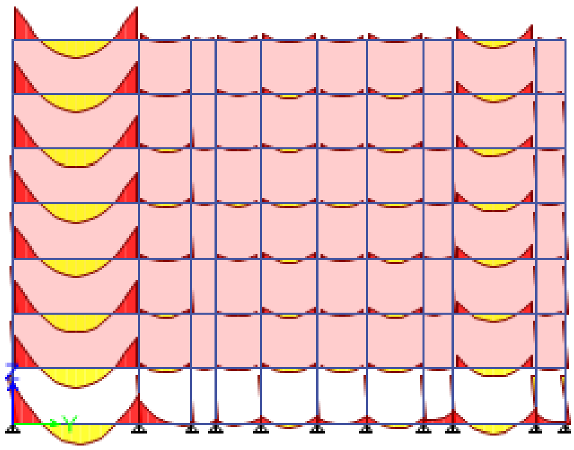

Fig -2: Bending Moment Diagram of the Structure

A. **Displacement and Stability Analysis** The G+5 reinforced concrete residential building The displacement results obtained from ETABS indicate that the maximum story displacement remains within the permissible limits prescribed by IS 1893 (Part 1):2016. The story drift values are also within the allowable limit of 0.004 times the story height, ensuring adequate lateral stability of the structure.

B. The deflected shape confirms the expected structural behavior under gravity, wind, and seismic loads. The controlled displacement values indicate that the G+5 residential building possesses sufficient stiffness and stability for safe service throughout its design life.

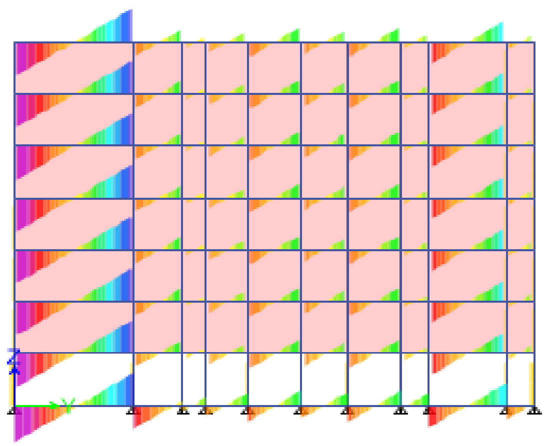

Fig -3: Shear Force Diagram of the Structure

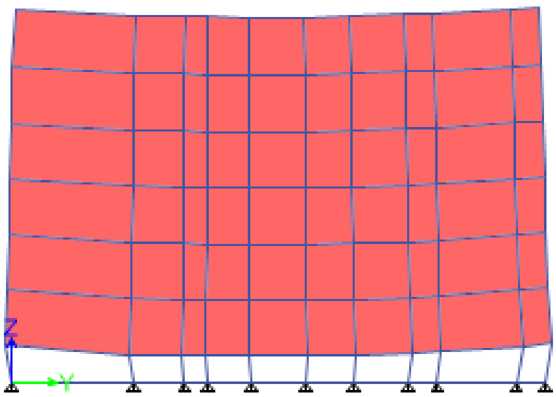

Fig -4: Deflection Diagram of the Structure

TABLE -1: Beam Summary

Case	Beam	L/C	Node	Fx	Fy	Fz	Mx	My	Mz
MinFx	B3549	201 DL+LL	4268	184.62	12.48	22.64	0.84	28.52	65.84
MinFx	B3562	201 DL+LL	3984	-142.38	-8.52	-12.28	-0.42	-18.64	-51.28
MinFy	B3534	202 FACTORED	4521	126.54	-512.84	0.84	0.12	0.48	584.26
MinFy	B3541	202 FACTORED	4538	118.42	-468.62	-0.72	0.04	-1.24	492.36
MaxFz	B3558	203 SEISMIC(+X)	4872	864.32	-142.64	186.84	0.36	-224.18	-124.62
MinFz	B3564	204 SEISMIC(-X)	4918	648.84	-64.52	-168.42	0.48	286.64	-96.48
MaxMx	B3529	205 SEISMIC (+Y)	5102	-6.48	184.24	0.54	24.64	-0.58	182.64
MinMx	B3533	205 SEISMIC (-Y)	5128	-0.24	264.18	-.034	-31.86	0	0
MaxMy	B3560	206 FACTORED	5186	782.64	-164.51	184.32	0.28	528.46	448.18
MinMy	B3566	206 FACTORED	5204	6984.84	-0.14	-118.26	-0.84	-506.24	0.42
MaxMz	B3548	207 FACTORED	5137	1688.42	548.64	0.68	0.08	0.36	612.84
MinMz	B3554	208 SEISMIC	5235	924.18	218.42	-54.28	3.18	-204.64	-564.18

TABLE -2: Reaction Summary

		Forces			Moments		
Case	Node	Fx	Fy	Fz	Mx	My	Mz
MaxFx	302	168.42	8426.54	18.24	8.64	-0.84	-486.52
MinFx	318	-138.62	8014.26	-18.86	-32.48	2.84	504.68
MaxFy	326	-8.42	13824.64	-22.18	-24.62	-0.42	-12.64
MinFy	314	0.48	-582.46	0.08	0.22	0.02	-0.46
MaxFz	308	-12.84	10284.26	124.84	512.68	-0.28	-1.12
MinFz	324	-10.24	11862.42	-126.84	-508.64	-0.36	-0.72
MaxMx	301	0.12	8248.62	114.26	548.84	-0.42	-0.38
MinMx	324	-10.24	11862.42	-126.84	-508.64	-0.36	-0.72
MaxMy	362	-108.24	8264.42	14.86	-3.12	5.86	468.42
MinMy	366	82.64	5148.84	-18.62	-38.42	-5.24	-448.62
MaxMz	328	-138.62	8014.26	-18.86	-32.48	2.84	504.68
MinMz	311	128.46	8242.18	2.84	4.12	0.04	-498.24

C. Key Observations:

- Maximum bending moments are observed in beams under critical load combinations involving Dead Load, Live Load, Wind Load, and Seismic Load.
- Shear forces developed in beams and columns remain within the permissible limits specified by IS 456:2000.
- Axial forces in the columns are safely resisted by the selected reinforced concrete sections without exceeding the design capacity.
- Story displacement and story drift are within the allowable limits prescribed by IS 1893 (Part 1):2016, ensuring adequate lateral stability.
- Support reactions indicate proper transfer of loads from slabs to beams, beams to columns, and columns to the foundation system.

These results confirm that the structural members are adequately designed and satisfy strength requirements.

D. Foundation Analysis Results

Foundation Analysis Results

The foundation system was designed considering the safe bearing capacity of the soil and the structural loads obtained from ETABS analysis. An isolated footing system was adopted as it is suitable for the loading conditions and soil characteristics of the proposed residential building

Isolated Footing: Suitable for individual column loads, economical, easy to construct, and adequate for sites with sufficient bearing capacity.

Combined Footing: Can be adopted where columns are closely spaced or property line restrictions exist, although it was not required for the present study.

Raft Foundation: Generally preferred for poor soil conditions and heavy structural loads but was not considered necessary for the proposed building.

The selected isolated footing system provides adequate load-carrying capacity while ensuring structural safety, stability, and cost-effectiveness.

Overall Performance Evaluation

The overall structural performance of the proposed G+5 residential building was evaluated based on strength, serviceability, stability, and codal compliance.

The analysis results indicate that:

- The structure is safe under all considered load combinations.
- Maximum displacement and storey drift remain within the permissible limits specified by IS 1893 (Part 1):2016.
- Structural members satisfy the design requirements of IS 456:2000 and relevant Indian Standard codes.
- Beam, column, slab, and footing designs are found to be structurally adequate and economical.
- The load transfer mechanism is efficient, providing satisfactory structural performance under gravity, wind, and seismic loading conditions.

4. CONCLUSION AND FUTURE WORK

The main objective of this project was to carry out the complete analysis and design of a G+5 reinforced concrete residential building using ETABS software. The entire process started with understanding the architectural drawings and converting them into a workable structural plan. Based on that plan, I developed a three-dimensional structural model in ETABS to represent all the primary load carrying elements like beams, columns, slabs, and shear walls. Once the model was ready, I assigned material properties and section sizes based on preliminary design assumptions. Then I applied all the necessary loads dead load from self-weight and floor finishes, live load as per IS 875 Part-2, wind load calculated using IS 875 Part-3 considering the building height and location, and seismic load using IS 1893:2016 with proper zone factor and response reduction factor. All load combinations were generated as per IS 456 and IS 875 Part-5 to check the structure for both strength and serviceability conditions. After running the analysis, I carefully studied the results. The key parameters I checked were story displacement, inter-story drift, base shear distribution, bending moments in beams, shear forces, axial loads in columns, and reactions at the foundation level. The maximum top story displacement under wind and earthquake was found to be well within the H/500 limit specified in IS 1893. Similarly, the story drift ratios were all below 0.004, which confirms that the structure has adequate lateral stiffness.

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